DEPARTMENT OF COMMERCE

BUREAU OF STANDARDS

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BUREAU OF STANDARDS.

INTRODUCTION.

The Bureau of Standards is charged with the custody, maintenance, and intercomparison of all classes of standards. Standards as used in this connection mean more than the mere standards of weight and measure. Thus there are standards in the field of electricity, heat, optics, and in fact in almost every line of work. For the purpose of organization, the scientific staff of the bureau is divided into nine divisions. This arrangement is based not on the class of standards but on the character of the work. Thus all experts in the electrical field are grouped together into what is known as the electrical division. Experts in the field of weights and measures form the weights and measures division, while those versed in temperature measurements make up the division of heat and thermometry. A description of the work of each of the divisions follows.

THE ELECTRICAL DIVISION.

As in the case of nearly all other kinds of work, one of the most important functions of the bureau with respect to electricity and allied subjects is the establishment and maintenance of the fundamental standards upon which all electrical measurements are based, including cooperation with similar institutions in other countries so as to secure international uniformity. This includes the intercomparison of standards and extensive research in methods of measurement and the development and improvement of subsidiary and derived standards. These standards are utilized and the results of the researches are immediately applied in the testing of reference standards and instruments for manufacturers, testing laboratories, universities, research institutions, electrical utilities, utility commissions, engineering and other interests, and various agencies of the Government.

The testing of electrical instruments and apparatus is of two main classes: First, there is the standardization of reference standards and precision instruments for manufacturing and other institutions which themselves make or standardize instruments for commercial use or which conduct research work. It is through the work of such institutions that the measurements made in practice are referred back to the standards of the bureau. Second, a limited amount of testing of commercial electrical measuring instruments and devices, such as radio and polarimetric apparatus, magnetic materials, ignition appliances, etc., is done chiefly

for the purpose of keeping the bureau in touch with the needs of the industries, of developing improved methods of manufacture, and of improving apparatus and materials. The greater portion of this testing is done for the Government services and takes the form of acceptance tests of materials purchased by other Government departments. This work serves the double purpose of providing information to be used in formulating specifications and of determining the quality of materials furnished in compliance with them. The research work has mainly to do with methods of measurement, the determination of the electric and magnetic properties of materials, and the development of those phases of electrical engineering in which measurement plays an important rôle. Electrical, radio, and illuminating engineering interests are all served by these investigations. The bureau also renders important service both directly and indirectly to manufacturing and other industries. Much of this investigational work is on the more fundamental aspects of the principles involved, so that the results may be applicable to a class of problems rather than being limited to the one specific problem under investigation. Examples of this work are to be found in the correlation of magnetic and mechanical properties of iron and steel and in the study of galvanometers. Research work in radio communication, magnetism, radio activities, photometry, gas engine ignition work, etc., is along lines quite similar to that in the more purely electrical measurements. Standards have been and are being developed, methods of measurements are being improved, and important special problems of significance to the industries—and in a number of cases of particular importance to the Government—are being investigated.

One of the valuable services which the electrical division renders to the Government and also to the industries and public is the routine testing of incandescent electric lamps. For a number of years all Government purchases of this class of material have been based on acceptance tests conducted by the bureau. The standards of manufacture have thus been raised and much valuable information has been secured concerning the life and efficiency of these lamps. During the fiscal year ended June 30, 1921, the Government alone placed orders for about 3,000,000 incandescent electric lamps. All these were purchased on the basis of sample lamps tested at the bureau.

The testing of dry cells and storage batteries under all conditions of operation and the work in standardization of sizes of dry cells is of the first importance, since almost everyone is a user of such appliances.

The research work in the field of radio communication has yielded very important results. The construction of a satisfactory form of radio direction finder by means of which ships are able to determine the location of lighthouses, etc., many miles away, and when entirely obscured by distance and by fogs, would alone warrant a good portion of this investigation.

The electrical division has carried out certain investigations which, while not strictly electrical in their nature, are closely allied with illumination or similar work. Among these may be included the investigation of illuminating and natural-gas service conditions in various cities and States throughout the country, and the investigation and tests of all forms of gas stoves and burners. The extensive surveys which the bureau has made in these fields have greatly aided in the establishment of better relations between the public service corporations, State and municipal governments, and the public. A similar statement might be made in regard to the important work on electrolysis mitigation.

As mentioned in the portion of this pamphlet devoted to the bureau's relations to the Government and the public, it should be borne in mind that the assistance of an impartial third party in the case of disputes, such as those referred to above, does much more to satisfactorily settle the question than long drawn-out quarrels in the courts.

Of late years there has been a growing necessity for the standardization of safety codes in our industrial establishments. The bureau has taken an active part in the unifying of such regulations, and a good portion of this work has been assigned to the members of the staff of the electrical division.

The telephone service standardization work is also of the first importance and should result in better service and more satifsactory relations between the telephone companies and the public.

THE DIVISION OF WEIGHTS AND MEASURES.

The original standardization work that was carried out by the ancients was in connection with the familiar measurements of length and mass. Standardization of these measurements is absolutely essential in any civilization, however primitive. The division of weights and measures may, therefore, be considered to deal with the fundamental work from which all the rest has grown.

This division is charged with the custody of the fundamental standards of the United States. It is probably not generally known that we have no primary standard yard or pound. Our fundamental standards of length and mass are the meter and kilogram which were sent to this country from France by the international bureau in 1889. Our standard yard and pound are derived from these, which are duplicates of the international prototypes kept at Paris. The working standards which the bureau uses in making comparisons with weights and measures submitted to it for test are compared at regular intervals with the fundamental standards of the country, and thus our measurements are in reality referred back to the standards deposited in the international bureau at Paris.

The bureau conducts a large number of tests of sets of weights for various private and State institutions and for the industries. As these tests entail a considerable amount of work and require a great deal of time, it is not always possible for the bureau to undertake all of the work of this nature that it would like to do. It is therefore important that its activities be confined to the testing of reference standards, as the ordinary routine testing of weights is a problem which suitably belongs to the commercial laboratory.

The thoroughly practical nature of the weights and measures work will be appreciated when one learns that the bureau has two well-equipped cars for calibrating railroad track scales. These cars are high-capacity box cars, specially constructed to hold a set of weights, with a total weight of 100,000 pounds. By means of a crane attached to the car and operated by a gasoline engine these weights can be loaded onto the scale and its reading compared with the actual load placed upon it. Such an equipment is much more accurate and reliable than the ordinary single dead-weight test car which most railroads use for this purpose. The bureau, however, also owns some cars of this type for less accurate work. The weights in the larger test cars just mentioned are well protected inside the car and are not subject to the wear and consequent variation which is bound to occur in the case where the car itself is used as the weight.

For the inspection and calibration of mine scales, which in many cases are located in almost inaccessible territory, the bureau maintains specially built motor trucks which serve the same purpose (to transport dead weights) as the cars mentioned above. These mine-scale testing equipments have done a great service in aiding to settle disputes between mine operators and the workers and in assuring the giving of honest weights to the consumer.

During the war munitions were produced in vast quantities in this country. The making of shells and similar articles on an absolutely interchangeable basis required the use of a great number of accurate gauges. The bureau took a leading part in assisting the military departments in this work. Its assistance took not only the form of routine testing of large numbers of gauges but also the manufacture of gauge blocks, an industry theretofore confined entirely to one firm in Europe. This process has now been perfected and adopted by one of the leading makers of precision tools in the United States.

One of the laboratories of the weights and measures division is devoted to the testing of clocks and watches. This work has grown from small proportions before the war to quite an important part of the bureau's activities. Many hundreds of clocks and watches have been tested for the United States Shipping Board and the War Department. Until recently no ship's chronometers were made in this country, but it is likely that since the need for such articles has been recognized the industry will obtain a footing in the United States. In this development

work the bureau has played an important part. Other laboratories are devoted to the testing of volumetric glassware, large quantities of which are constantly submitted to the bureau for test and certification.

THE DIVISION OF HEAT AND THERMOMETRY.

An idea of a portion of the work of this division is quite evident from its title, but the breadth of the field covered in the study of the phenomena of heat is probably not appreciated by the average nonscientific man. It is true that a large part of the work of this division consists of the calibration of thermometers of all sorts, as may be judged from the completeness of the thermometer laboratory. The bureau's work in aiding to place the manufacture of clinical thermometers on a more scientific and honest basis has been of great importance. The work is much broader than this, however, and includes investigations of the melting points of various materials and the establishment of fixed points on the high temperature thermometric scale. Such work requires the use of a great deal of special apparatus and the highest degree of scientific ability. It is of great importance in many of the industries which are dependent upon the accurate control of very high temperatures.

Standard samples for use in calorimetric work are distributed by the bureau and serve as reference standards in the industries.

The production of extremely low temperatures and the liquefaction of air and hydrogen and ultimately of helium is carried on by this division. The plant provided for this purpose is a very complete one and is operated once or twice a week to maintain the necessary quantities of liquid air in stock. Valuable assistance to the refrigerating industries has been given through the investigations conducted by the heat division.

An interesting part of the work of this division is that concerned with the investigation of internal-combustion engines, particularly those used for automobiles and airplanes. Prior to the establishment of the bureau's laboratory for this purpose, no testing of such engines under conditions comparable to those of actual service had been carried out. The bureau constructed a special laboratory containing a chamber within which an airplane engine could be placed and operated under the conditions of low atmospheric pressure and temperature met with at the high altitudes at which planes often fly. This work was of great value to our Air Service during the war. Extensive investigational and development work on automobile engines and appliances, including the testing of cars on the road, has likewise been conducted. The results obtained in these tests are of great value to engine designers and will result in a better utilization of gasoline and in a better running automobile.

The determination of the fireproofing qualities of various materials is of great importance in building construction, and this division, in cooperation with various organizations, has conducted a thorough investigation of numerous fireproofing materials, fireproof coatings for building columns,

etc. Results of great value have been obtained, and it is thought that considerable aid will be given to architects and engineers through this work.

THE OPTICAL DIVISION.

Optical instruments and optical methods are used in nearly all branches of science and the purely scientific investigations carried out in the laboratory often have an important application in practical work. One of the sections of this division is engaged with the study of spectroscopy—that is, the determination of the spectra of the various chemical elements. Such work is of great importance in the analysis of certain substances and is being used to a greater extent each year in the industries. In connection with spectroscopy, the bureau developed some special photographic plates which were sensitive to the longer or red waves of the spectrum. As showing how a scientific achievement may very often have an intensely practical application, photographic plates developed in connection with spectroscopic analysis proved to be the best obtainable plates for aerial photography. By using such plates photographs could be taken through haze, smoke, and clouds which might happen to be below the airplane. Camouflaged objects were also easily distinguished, owing to the fact that, when photographed on these specially sensitized plates through a suitable color screen, the colors, while looking the same to the naked eye, had a distinctly different appearance.

Another optical field of great importance to the industries is that of polarimetry. As the polarimetric examination of sugar is one of the most important tests of that commodity, the bureau has undertaken the work of standardizing and in certain cases of adjusting polariscopes submitted to it by the sugar refiners. In this way it has been of real benefit to this industry, as such instruments could not be readily procured during the war and many that were in use were in bad condition. The bureau's laboratories have produced a number of the rare sugars for medical and other work.

The section of the bureau devoted to colorimetry carries on some important work. The study of colors and color standards is of great importance in many lines of industry. Many kinds of oils and other liquids are sold on the basis of color, and the use of accurate standards in this work is of the first importance. This section is also engaged in the testing of eye-protective glasses, such as are used by workmen to guard their eyes from injurious radiations. The bureau has found that many of the glasses ordinarily sold are of little value for such use, while others are quite satisfactory. Its work in this field is of very great and direct benefit to the country. Its work on the colored glasses used for railway signal lights should also be mentioned. During the war a number of special investigations concerned with colorimetry were carried out, such as a means for signaling by invisible radiations,

various methods for the detection of invisible writing, and color-camouflaged signaling devices. An elaborate investigation of high-power military searchlights was initiated during the war and is still in progress; it includes the complete investigation of the light source in such lamps and the distribution of illumination throughout the beam.

Another section of this division deals with optical instruments and has devoted a great deal of time to the study of the design of this class of apparatus. Nearly all these instruments were previously made abroad, but a number of American firms are now entering the field, and it is the desire of the bureau to assist them in every way possible. A great many binoculars and other optical devices were required by the military and naval branches of the Government service during the war. Nearly all of such instruments were first tested by the bureau and rapid but accurate methods of determining the constants of optical instruments were perfected in this laboratory.

The use of radiometry for purposes of secret signaling was a system developed during the war and which has been carried by the bureau to a practical point.

Interferometry, or the interference of light waves, has been used to measure small changes of length, and plays an important part in the testing of extremely accurate gauges, such as were used in the production of munitions. In this work the optical division cooperated closely with the division of weights and measures, and also with the military departments.

THE CHEMISTRY DIVISION.

We have already mentioned in this pamphlet that a great deal of the work of the chemistry division is in cooperation with the other eight scientific divisions of the bureau. Many of the problems which come to the bureau for solution demand chemical analyses as a part of the work. It must not be inferred, however, that the chemistry division does not initiate and deal with many independent investigations. It likewise carries on many tests purely chemical in their nature for other Government departments and in some cases for municipal institutions and private parties. It also distributes many standard samples of various materials which are used for reference purposes in the industries. This work alone is of the greatest importance. In certain of the work carried on by the bureau absolutely pure substances are necessary, and the preparation of these forms a part of the activities of the chemistry division.

The field of electrochemistry is becoming more important each year, and in the solution of such problems the bureau has taken an active part. Accurate data are lacking on a good many of the processes of electroplating, and the work of the chemical division has been of real assistance to this industry.

In the case of the section on metals and ore analysis, the work is carried on in cooperation with the metallurgical division, the two being very closely related.

Another section devoted to gas chemistry has been largely employed during the past few years on the testing and investigation of the properties of balloon fabrics and the development of automatic gas analysis apparatus. This latter work has been of great importance to the nitrate division of the Ordnance Department of the Army and was used in analyzing the gas for balloon purposes obtained from the Government's helium plants.

In connection with the study of reagents and chemical apparatus the bureau has been actively employed in testing various substitutes for platinum ordinarily used in the making of certain chemical vessels and in the production of platinum of unusual purity. A great many tests have been carried out by the bureau on platinum substitutes, but none have been found which can entirely replace platinum for certain uses.

Chemical work enters into all the investigations of such substances as lubricating oils, rubber, leather, paper, textiles, ink, glue, etc. In this work the chemical division performs the analytical tests, while the physical strength and other investigations are handled by the division of structural, miscellaneous, and engineering materials.

Chemical work is also important in the testing of cement, bituminous materials, paint, varnishes, and soap. The Government is a large buyer of all classes of these substances, and nearly all of the acceptance tests, to determine whether the article supplied complies with the Government specifications, are performed by the chemical division of the bureau.

ENGINEERING PHYSICS.

While this division is one of the newer ones of the bureau, its work is, nevertheless, of great variety and importance. It includes the testing of such appliances as water current meters, ventilators, fire extinguishers pressure gauges, fittings for heating systems, aeronautic and similar measuring instruments, the determination of the aerodynamical properties of model airplanes in the bureau's wind tunnels, and the study of sound and allied subjects. The last-named work is very important to the architect and user of building materials, since sound-proofness and sound transmission are important matters in the design of structures. Two of the three wind tunnels belonging to this division give an air speed of 90 miles per hour, while 190 miles per hour may be obtained in the third. The balances on which the specimens are mounted are designed to care for all sorts of work, from the testing of very heavy specimens, such as sections of airplane radiators, to the finest and most accurate kind of work on model aerofoils, etc.

The tests of aeronautic instruments really serve to place the manufacture of such devices on an accurate basis, as but little work had been done

in the field when the bureau started its investigations. Since the war this section has devoted itself to somewhat similar problems along broader lines.

STRUCTURAL, MISCELLANEOUS, AND ENGINEERING MATERIALS.

This division is preeminently the industrial division of the bureau. Its work is carried on in close cooperation with the various industries of the country and includes the investigation and testing of the ordinary materials used for constructional work and in the making of rubber and leather goods, textiles, and paper.

One section is devoted to the testing of metals and wood and is equipped with machines capable of determining the properties of any size specimen from the lightest piece of wood to a full-size steel column. One of the emery-testing machines which is assigned to this section is the largest precision testing machine in the world. It has a capacity of 2,300,000 pounds in compression and about one-half that in tension. It is so designed that both tensile and compressive strength tests can be carried out with the highest degree of accuracy and with the maximum of convenience. Besides this machine, the bureau owns a still larger compression testing machine having a total capacity of 10,000,000 pounds. This is at present located in the branch laboratory of the Bureau of Standards at Pittsburgh, Pa., but it is the intention to move it to the Washington plant as soon as opportunity permits. The mechanical equipment of this section includes, besides the tensile and compressive machines just mentioned, a full assortment of torsional, cross bend, impact, and hardness testing machines.

The investigation of airplane woods conducted by this section before and during the war is the most complete ever attempted. Its service to the Government consists in a large amount of routine testing of steel and other substances and in certain investigations requiring the accurate determination of the physical properties of materials.

The second section of this division deals with investigations of cement and concrete. It is equipped to carry out work both in the laboratory and in the field, and conducts at all times a great number of routine tests of cement used in governmental construction work. This part of the bureau's work assumed such large proportions during the war that it was necessary to establish a number of branch laboratories devoted to cement testing. These greatly aided the Government in rapidly carrying out its program in the construction of wharves, warehouses, cantonments, etc. The investigational work on cement and concrete during the war was quite largely devoted to the perfecting of a particularly light and strong concrete for use in ship construction. Through the bureau's efforts, and by the use of a so-called light-weight aggregate, a concrete giving a strength many times that usually obtained in building construction was produced, thus enabling the United States Ship-

ping Board to build concrete vessels of maximum carrying capacity with minimum weight.

Closely allied to the work on cement and concrete is that conducted by the bureau on lime and similar material. This work includes investigations of the effect of different kinds of lime upon the properties of concrete, possible ways for the improving of the quality of lime plaster, and investigations of the best means for manufacturing sand-lime brick. Some work has also been done on the use of reinforced gypsum and means has been developed whereby the strength and waterproofness of this material may be increased.

Other sections of this division are concerned with the physical testing of rubber, leather, textiles, and paper. This work necessarily requires familiarity with all of the manufacturing processes used in the production of the finished articles and in order to enable the bureau to test the relative merits of various manufacturing processes a small size but complete rubber mill and paper mill have been provided. The textile section is quite completely equipped with cotton mill machinery and a number of special appliances for the rapid and accurate testing of cloths.

A constant-humidity room for testing paper and textiles under accurately controlled conditions forms part of the unusual equipment of this division.

THE METALLURGICAL DIVISION.

This division is concerned with the thermal analysis and structure of metals, heat treatment and its effect upon metals and alloys, including the researches involved in determining the causes of metal failures, the study of heating and cooling curves, the investigation of hardening, annealing, tempering, cementation, determination of the critical ranges, and the preparation of pure metals and alloys. In connection with this division one of the few experimental foundries in existence is operated. This is equipped with furnaces suitable for the melting of both ferrous and nonferrous alloys. Besides being employed in investigational work, it runs out quite a number of castings used in the bureau's machine shops for the construction of special apparatus. Foundry practice in connection with various kinds of metals can thus be studied and a great deal of valuable information is also obtained concerning furnace behavior, the relative merits of various types of foundry sands, etc. For studying the numerous phases of the working of metals, a small-size electrically driven rolling mill, a forging press, and other similar equipment has been installed. The laboratory devoted to microphotographic work, in connection with the microscopy and structure of metals, is unusually complete. Valuable work has been done here on the causes of failure of railroad rails and similar important problems. An experimental heat-treating plant in which the effects of high temperatures on various alloys of steel can be studied is maintained by this division. Many special inves-

tigations, such as the determination of the causes of failure of car wheels, are continually carried on for the benefit of metallurgical industries of the country. In cooperation with the chemical division, analyses of metals are conducted and pure metals and alloys are produced for scientific purposes.

A great deal of investigational work is carried on in this division to determine the best composition for brass, copper, bronze, and similar materials needed by other departments of the Government.

THE CERAMICS DIVISION.

The first section of this division is concerned with clay products, the development of new uses for clay, the replacement of imported by native materials, improvement of the quality of clay products, and in making routine tests for the Government involving the use of clays and similar materials.

An important work of this division is in connection with refractories of all sorts for use in furnaces and other places where high temperatures must be withstood. In cooperation with the section devoted to the manufacture of optical glass, a special form of glass pot has been developed using for the material a refuse from earthenware and wall tile manufacturing plants. The use of these pots promises to revolutionize one portion of the optical industry, and they are already employed commercially by several glass makers.

Strength tests are conducted on hollow-tile walls and construction, using architectural terra cotta and similar materials, and in cooperation with Division III, considerable work has been done on the investigation of fire-resisting protective coatings for building columns.

Section 2 of the ceramic division is devoted to the manufacture of optical glass. It should be noted that only a few years ago not a pound of optical glass was produced in the United States; all of it was imported from a few firms in Germany, France, and England. The bureau foresaw that in the event of an emergency this supply might be greatly curtailed. After the commencement of the war in Europe the bureau undertook a complete study of the manufacture of this kind of glass and at the time the United States entered the conflict it had worked out a satisfactory process for producing the ordinary grades of optical glass. It was only after a long and exhaustive investigation that the proper technique for the operation of the furnace, the best design and most satisfactory materials for use in constructing the glass pots, etc., could be worked out, and the final result—the production of high-grade optical glass—is one of the most important accomplishments of the bureau. This work has all been conducted in the closest cooperation with and for the benefit of the American glass industry. The results have been freely given to all those interested, and several firms are now manufacturing a good grade of optical glass.

Another section of the ceramics division is concerned with the study of enamels for use on metal ware. The production of satisfactory enamels for this purpose was an art previously known only in Europe, and the development of satisfactory processes in the United States is of extreme importance. While the work has not been under way for any great length of time, important results have already been brought about, and it is believed that eventually an enamel in every way as satisfactory as that produced abroad will be developed.

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